CHAPTER 10

DESIGN OF LOCK APPROACHES

Section I. Upper Lock Approach

10-1. Navigation Conditions. Navigation conditions within the upper approach to a lock can affect the safety of tows approaching or leaving the lock and the time required for tows to transit the lock. Conditions for downbound tows can be particularly hazardous if high current velocities and crosscurrents prevail. Properly designed guard and guide walls can assist tows in approaching and leaving the lock. Locks with long guide walls and short guard walls will tend to have currents along the guide wall and crosscurrents near the end of the guard wall. Locks with long guard walls and short guide walls will tend to develop crosscurrents near the end of the guard wall. The intensity or the effects of crosscurrents can be reduced or eliminated by providing ports in the upper guard wall, by reducing velocities in the approach channel by means of structures, or by extension of the guard wall using cells. Conditions in the upper approach can also be affected adversely by the alignment of currents upstream of the guard wall and uneven channel depths in the lock approach.

10-2. Ports in Guard Wall. Ports in the upper guard wall eliminate or reduce crosscurrents near the end of the wall by permitting all or a major portion of the flow intercepted by the wall to pass under the wall. The effectiveness of the ports will depend on their number, size, and hydraulic efficiency based on the type of construction. As a general rule, the total cross-sectional area of the port openings should be equivalent to the total cross-sectional area of the approach channel affected by the locks and lock walls. Flow through the ports will tend to move a tow toward the wall, and could make it difficult for tows to pull away from the wall. This effect can be reduced by placing the top of each port below what would be the bottom of a loaded barge locking at normal pool, with a relatively deep channel between the guard wall and adjacent bank. In most cases, placing the tops of the ports 4 to 6 feet below the bottom of a loaded barge at normal pool would be adequate; at structures with hinged pool operation, the tops of ports might have to be somewhat lower. The bottom of the channel between the guard wall and the adjacent bank should be near or lower than the elevation of the bottom of the ports to reduce velocities for tows approaching the wall and prevent a buildup of head against the land side of the tow. In riverbeds of easily erodible material, the bottom of the ports should be protected from scouring, particularly those near the lower end of the wall. Without protection, the ports near the lock would tend to scour and pass more of the flow with a corresponding reduction in flow through the ports near the upper end. Increasing the concentration of flow through the lower ports would increase the tendency for tows to be moved toward the wall; this could also affect flow through the dam gates near the lock.

10-3. Effect of Ports on Movement of Ice and Debris. With properly designed ports and approach conditions, tows can be made to drift into the lock approach and become aligned along the guard wall with little or no rudder control. However, ports in the upper guard wall will increase the tendency for ice and floating debris to be trapped in the lock approach. A long guide wall and short guard wall will reduce the amount of debris trapped in the lock approach but, at the same time, will generally preclude the use of an adequate number of ports to eliminate or substantially reduce crosscurrents near the end of the wall. When adjacent locks are used with a guide wall on the land-side lock, currents moving toward the ported guard wall of the river-side lock could cause difficulties for downbound tows approaching the guide wall on the land-side lock.

10-4. Channel Depths. Differences in depth in the approach channel can affect the movement of tows in the approach, particularly if the tow is moving at reduced speed from deep to shallow water. Tows moving along a bank and passing from a deep to a shallow portion of the channel block a portion of the flow in the shallow channel, causing a higher water level to develop between the tow and the adjacent bank that could move first the head and then the remainder of the tow riverward. The effects of changes in depths can be minimized or eliminated with submerged dikes or groins located some distance upstream of the lock walls. Submerged groins (dikes) can also be used to reduce velocities in the approach. The elevation and spacing of the groins would depend on channel depths and current direction and velocities. In previous studies, groins with crests 20 feet below normal upper pool elevation spaced 1 to 1-1/2 times the length of the upstream groin have proved satisfactory (fig. 10-1). The groins should extend from the bank at least to a line forming an extension of the land-side face of the upper guard wall. Dikes that are too high above the bed or spaced too far apart will tend to produce turbulence with erratic currents extending to the surface. These currents are usually local and have little or no effect on the movement of tows approaching or leaving the lock. The disturbance can be reduced by closer spacing of the dikes or by filling between dikes. A fill of the same elevation as the dikes would not be as effective in reducing velocities because of the reduction in channel roughness.

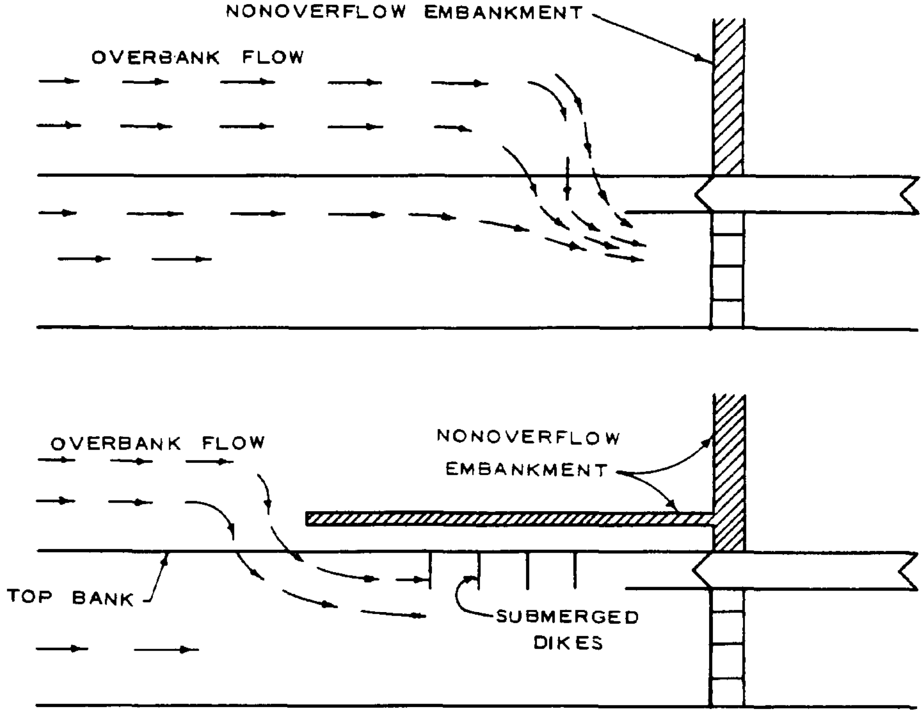

Figure 10-1. Effect of overbank flow and location of submerged dikes

10-5. Overbank Flow. Overbank flow moving toward the river from the adjacent bank or from the river toward the adjacent bank can produce serious crosscurrents (fig. 10-1). This condition can occur with a low overbank and an embankment blocking downstream flow or with a low overflow embankment with high ground upstream causing some flow toward the overbank. This condition can be eliminated or reduced by constructing a fill or dike along the adjacent bank extending from the dam or locks far enough upstream where tows can either avoid the currents created by the flow or maintain speed and rudder power required to overcome the effects of these currents (fig. 10-1). This distance would have to be two to more than four tow lengths upstream of the end of the guard or guide wall, depending on the amount of overbank flow. The fill or dike along the adjacent bank would also provide a guide for tows in determining channel limits. The top of the fill or dike would have to be at least as high as the elevation of the maximum navigable flow for maximum effectiveness.

Section II. Lower Lock Approach

10-6. Currents Affecting Navigation. Currents affecting navigation in the lower lock approach depend on channel alignment; flow from spillway, lock-emptying outlet, and powerhouse; and flow from or toward the overbank. Eddies forming in the lower lock approach and flow moving from the spillway toward the adjacent bank produce currents that could be objectionable to navigation attempting to approach the lower guide or guard wall (fig. 10-2). Bends in the channel a short distance downstream of the approach could increase the intensity of these currents and their effects on the movement of tows. A straight channel extending downstream of the lock would tend to provide better navigation conditions for tows approaching and leaving the lock. Eddies in the lower approach affect upbound tows because of the upstream currents along the bank and riverward currents at the upstream end of the eddy.

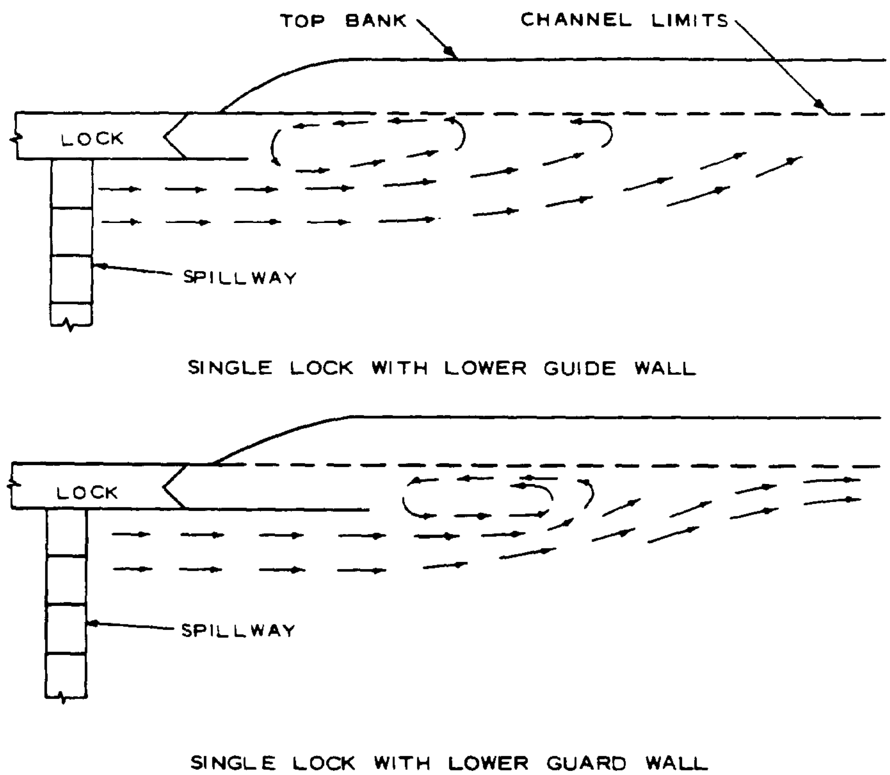

Figure 10-2. Currents in upper lock approach

10-7. Guide and Guard Walls. Guide or guard walls are used to assist upbound tows in approaching and becoming aligned for entrance into the lock. The selection of the type of wall depends on foundation conditions and currents that could be expected with the completed structure. Use of a guard wall instead of a guide wall would tend to facilitate the movement of tows approaching the wall since the outdraft currents would tend to move the tow toward the wall instead of away from the wall. A long guard wall could increase the head on the lower lock gates at the conclusion of a lock-emptying operation when the emptying outlet is on the river side of the lock. Model studies have indicated that installation of ports in the lower guard wall would, in most cases, have little or no effect on the eddy in the lower approach or on the head on the lower lock gate. Where the channel bends riverward of the approach, currents moving from the spillway toward the adjacent bank would tend to resist the movement of the head of a downbound tow in the direction of the bend in the channel. In this case, a guard wall with sufficient channel width landward of the wall would permit the tow to move its stern landward and turn riverward before being seriously affected by the currents. Where the channel bends in the direction of the land side of the lock, the effects of the spillway currents are reduced. However, in this case, sight distance would also be reduced for tows approaching along that side of the channel.

10-8. Overbank Flow. Low overbank areas or low dikes forming the lock-side bank line can create serious crosscurrents when there is substantial flow toward the overbank or over the dikes (fig. 10-3). These currents would tend to move the tow landward or resist the movement of downbound tows riverward. This condition can be alleviated by erecting a nonoverflow fill or dike along the top bank extending downstream of the end of the lock wall or by raising the elevation of the dikes within the channel to prevent any substantial flow over the dikes. Flow over the overbank or over the dikes would increase any shoaling tendencies existing in the channel along the bank or dikes.

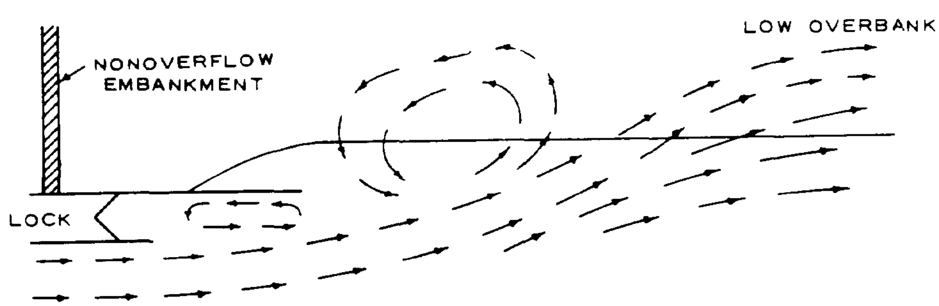

Figure 10-3. Low overbank adjacent to lock approach

Section III. Shoaling in Lock Approaches

10-9. Upper Lock Approach. In streams carrying sediment, shoaling in the approaches could be a factor and should be considered in the selection of a site for the lock and dam structure. The movement of sediment and formation of bars in the reach considered for the structures should indicate if a shoaling problem exists in the upper approach. In bends, a natural tendency exists for sediment to be moved away from the concave bank; but in relatively straight reaches, special treatment utilizing training structures might be required. Increasing flow toward the lock side of the channel to maintain depths would increase velocities and crosscurrents. By using a guard wall with ports, the crosscurrents can be reduced. Since the tops of ports must be below the bottom of the depth of loaded barges, velocities of the bottom currents are increased, reducing the tendency for shoaling in the approach to the lock landward of the guard wall.

10-10. Lower Lock Approach. Shoaling in the lower lock approach is a problem encountered at most structures located in sediment-carrying streams. The seriousness of the problem increases with the amount of sediment moving in the stream and will vary depending on the characteristics of the stream, particularly as affected by variations in discharge. Some of the sediment moving along the lock side of the channel is moved into and deposited in the lower lock approach channel where velocities are reduced by the sudden increase in channel width and depth downstream of the lock. Some deposition is also caused by the action of the eddy formed in the approach. Normally, in streams carrying a heavy sediment load, the channel is wider at the dam than farther downstream to provide for pier widths, elevation of the gate sill, and capacity of the spillway to pass uncontrolled flows with little increase in stage. Due to the greater channel width, some of the sediment moving through the dam during the higher flows could be deposited between the dam and the lower end of the lock wall. Because of the shallow depth and steeper slope in that reach, this material could then be moved downstream into the lock approach, even during controlled riverflows. Shoaling in the lower lock approach can be a serious, continuous problem unless remedied. Dredging in the approach would be costly and would interfere with traffic using the lock. In streams carrying a heavy sediment load, periodic dredging could be required since any shoaling on the approach side of the lock wall would make it difficult for tows to approach the wall and become aligned for entrance into the lock.

10-11. Reducing Shoaling in Lower Approach. Model studies indicated that a properly designed wing dike extending from the end of the riverward lock wall and angled slightly riverward would reduce the frequency and, in some cases, the amount of dredging. Experiences with the Arkansas River, which carries a heavy sediment load, indicated that these structures have reduced considerably the frequency and amount of dredging and, in some cases, have almost completely eliminated the shoaling problem. The wing dike is designed to permit sediment-free surface flow to move over the top of the dike and thus prevent or reduce the amount of sediment-laden bottom current that would move into the approach channel around the end of the dike. The dike must be high enough above the bed to prevent sediment from moving over the top and low enough to permit sufficient surface flow over the top to prevent the bottom currents from moving landward around the end of the dike. The wing dikes on the Arkansas River were about 400 to 600 feet long, angled about 10 degrees riverward of the lock wall with crest 2 to 3 feet above normal lower pool elevation (fig. 10-4). Reduced shoaling in the lower approach

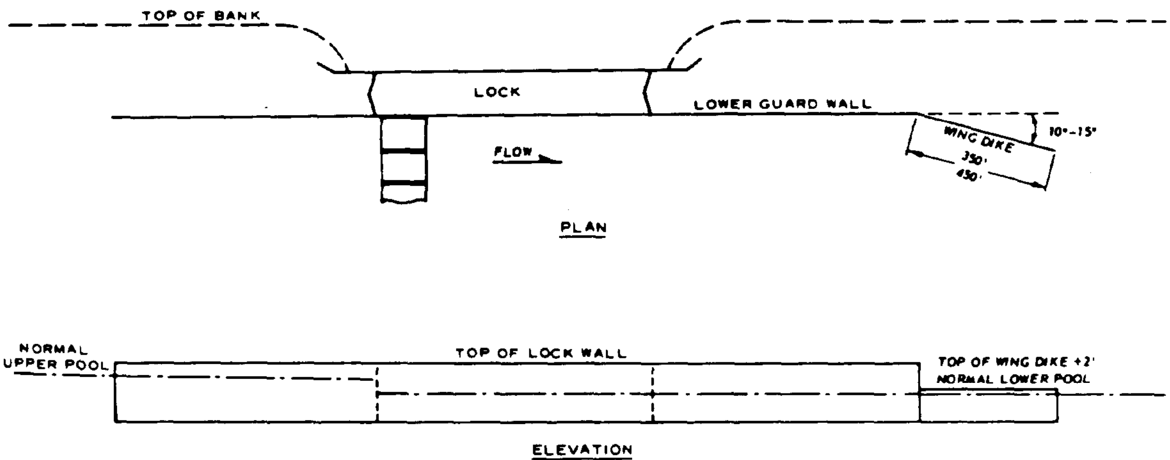

Figure 10-4. Wing dike used to minimize shoaling in lower lock approach

channel could be accomplished by opening the gates near the lock wider than those on the opposite side. This operation would cause some of the sediment deposited downstream of the dam to be moved toward the side of the closed or partially closed gates. Since little or no sediment is moved through the dam during controlled riverflows, the effectiveness of this plan would depend on the amount of deposition existing downstream of the dam during these flows. However, caution should be exercised during sediment flushing with this method to avoid scour which could undermine the riverward lock wall. Limited studies in movable-bed models indicated that bypassing flow into the lower lock approach through filling and emptying culverts, through the lock, or through a special bypass channel would reduce the tendency for shoaling, depending on the amount of flow introduced into the approach. This, however, would not be practical in removing shoals because of (a) the amount of water required to produce scouring velocities and (b) the dispersion of flow a short distance downstream of the lock walls.

Section IV. Lock-Emptying Outlets

10-12. Location of Outlets. The location of the lock-emptying outlet can affect upbound tows approaching the lock. The discharge during a lock-emptying operation with the emptying outlet located within the lock approach can create currents that could adversely affect tows approaching the guide or guard walls, depending on the location of the tow with respect to the outlet and wall and the discharge from the outlet. Since the currents would not be constant in intensity or direction, they could cause accidents or delays during the approach.

10-13. River Side of Locks. Location of the emptying outlet on the river side of the lock would generally have little or no effect on navigation approaching the lock, particularly when there is some flow through the dam gates near the lock. With the outlet placed on the river side of the lock, water-surface elevations at the emptying outlet could be higher than in the lower approach on the downstream side of the lock gates and could be sufficient to cause some difficulty in opening of the lower lock gates, particularly during high flows. This difference in elevation would depend on the velocities along the lock side of the channel, water-surface slope along the lock, and the distance from emptying outlet to the end of the river-side lock wall. The head on the lower gates at the conclusion of the lock-emptying operation can be reduced by placing a wall or rock dike along the upstream side of the lock-emptying outlet. The reduction required would depend on the velocity of currents passing over the outlet and the height of the wall or dike. Since the momentum of the flow past the ports would permit little or no flow through the ports, ports in the lower guard wall would, in most cases, have little effect in reducing the head on the lower lock gates. Generally, sediment deposition into and over the emptying outlet basin would have little effect on lock emptying. Limited tests have indicated that with a head differential (inside and outside the lock) of at least 10 feet greater than the height of the fill over the outlet, the fill material consisting mostly of clean sand would be removed by the emptying operation with little or no effect on lock-emptying time.

10-14. Outlets on Land Side and River Side of Lock. Emptying systems with discharges from the land side of the landward lock wall and river side of the riverward wall could be provided when there are adequate water areas on both sides of the lock. Such areas are available with some arrangements, particularly with U-frame type locks. Some reduction in construction cost would be realized with this emptying system since less lock wall would be required downstream of the lower gates than with the inside wall discharge. Deposition over the lock-emptying outlet could affect lock-emptying time and should be considered, particularly with outlets on the river side of the locks.

10-15. Surges in Canals. Locks with emptying systems discharging in navigation canals often require special provisions to reduce the magnitude of surges. The Bay Springs Lock on the Tennessee-Tombigbee Waterway uses a ported diffuser manifold which spreads the discharge uniformly across the downstream channel. Other canal projects have used off-channel surge basins which slowly return the discharge water to the canal. This system usually requires a special bypass to allow the last few feet of water in the chamber to flow directly to the canal, providing a more rapid equalization of the water level inside and outside the lock without producing excessive surges. Surges can also be reduced by increasing lock-emptying time with slower valve opening.

10-16. Filling from and Emptying into Adjacent River Channel. Locks in bypass canals with the dam in the adjacent river channel could have lock filling intakes and lock emptying outlets in the river channel to reduce surges. However, intakes in the river would not fill the lock to the same elevation as that of the water surface in the canal, and special arrangements would be required to either open the lock gates against a higher head or to fill the remainder of the lock from the canal. Discharges into the river channel would not permit the lock to empty to the same level as the water level in the canal downstream of the lock. In this case, a special bypass would be required to empty the remaining portion of the lock into the canal or to open the lower gates against a higher head.

Section V. Hydroplants

10-17. Effects of Operation. With the high cost of fuel, the use of hydro power plants in connection with navigation locks and dams has become more attractive and economically feasible and should be considered in the design of the project. Hydroplant operation, when included as part of the navigation project, can produce surges and currents that could be objectionable or hazardous for navigation. To reduce the effect of powerhouse operation, the power facilities should be on the side of the stream opposite the lock or locks when practicable. With this arrangement, power releases usually have little effect on navigation conditions when there is substantial flow through the spillway. With little or no flow through the spillway, flow from the powerhouse tailrace could produce adverse currents in the lower lock approach.

Conditions could be particularly objectionable during start-up and shutdown because of the surges created. The alignment of the powerhouse should be such that the discharge is not directed toward the lower lock approach. With powerhouse releases and no flow through the dam, a large eddy would form that could extend across the channel to below the lower end of the lock wall, producing currents moving back upstream toward and along the gated spillway back to the tailrace (fig. 10-5). The

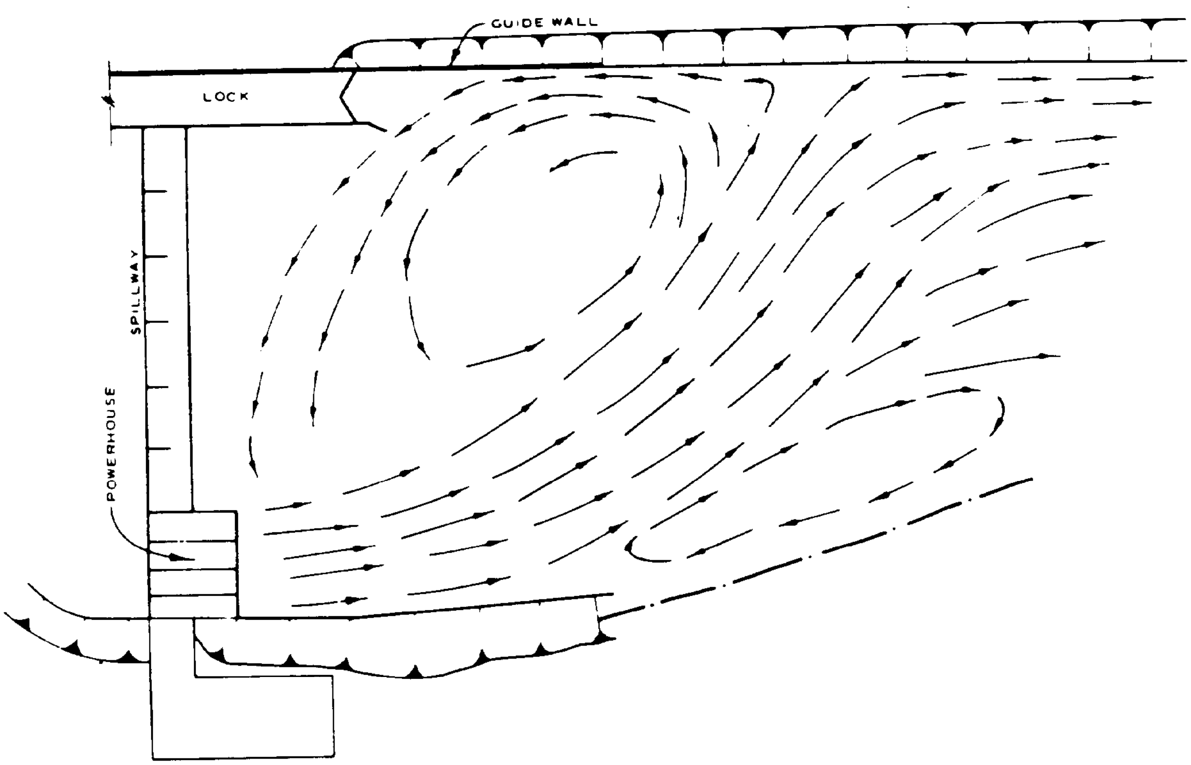

Figure 10-5. Effect of powerhouse releases on currents in lower lock approach

currents could also be hazardous for small boats navigating or drifting below the spillway since these currents would tend to move them into the tailrace; this condition can be eliminated or minimized by means of a splitter wall between the powerhouse and spillway as shown in figure 10-6. The eddy currents could be strong enough to move any sediment deposited in the area toward and into the lock approach channel. The effect of the eddy on navigation and on conditions in the lower approach can sometimes be eliminated by permitting some flow through the second or third gate from the lock. A flow equivalent to 20 to 25 percent of the powerhouse discharge has been adequate in some cases. The amount

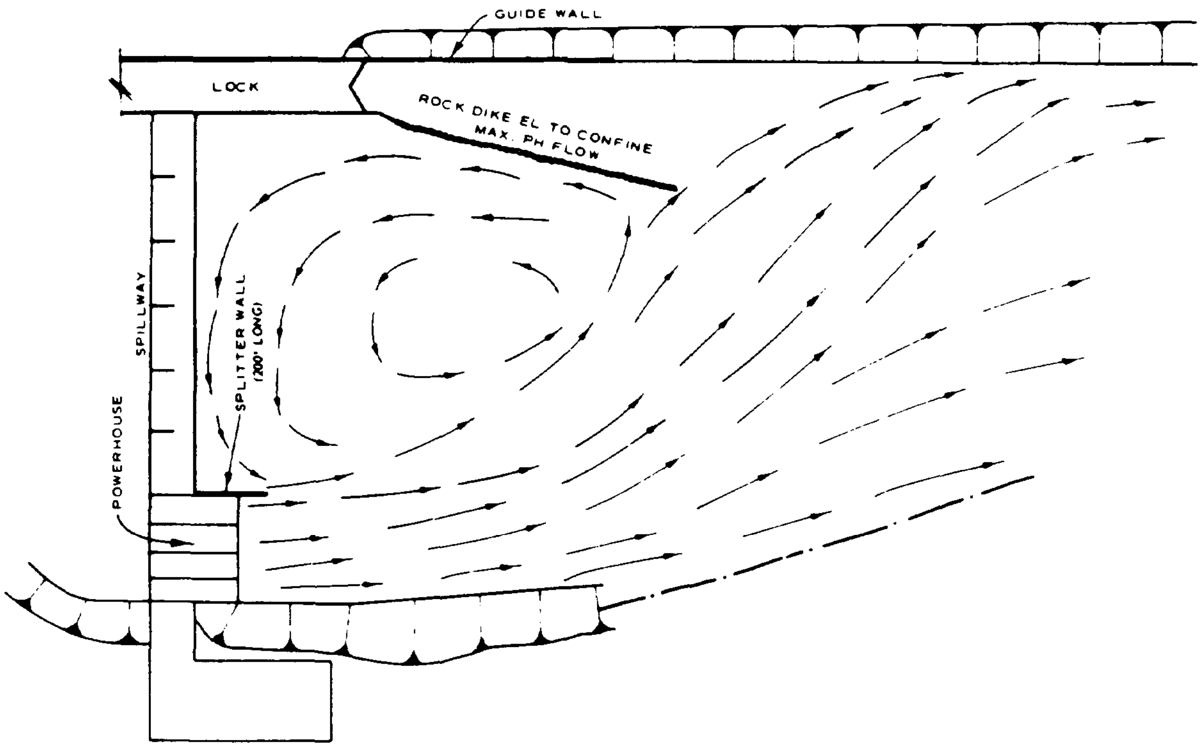

Figure 10-6. Dike used to minimize effect of powerhouse releases on navigation in lower lock approach

of flow needed to offset the effects of powerhouse releases will vary with each structure layout and channel configuration.

10-18. Reduction of Adverse Currents. The effect of the eddy on navigation can be reduced or eliminated by using a guard wall (river side) in place of a guide wall or by using a long rock dike angled riverward on the river side of a lock with a guide wall (fig. 10-6). In most cases the elevation of the dike needs to be only as high as the tailwater elevation with maximum powerhouse flow and no flow through the spillway. Surges in water level through the upper and lower pools during starting and stopping of powerhouse releases could create problems when there is little or no riverflow. The effect of hinged pool operation during intermittent powerhouse operation and the regulation of the rate of starting and stopping of units should be considered.